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2018 NISAR Applications Workshop: Agriculture and Soil Moisture

Workshop Report

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1 Executive Summary

Agricultural lands cover the globe and play an essential role in not only sustaining a growing global population, but can have significant implications on the Earth system through land use change (e.g., deforestation, grazing, etc.). As such, countries around the world have dedicated programs for managing these lands. Accurate and timely information concerning the status of agricultural crops (soil moisture, crop health, crop type, etc.) is essential to those nations' anthropogenic and ecological health as well as economy. The joint NASA/US Department of Agriculture Agricultural Research Service (USDA-ARS) workshop focused on advancing agriculture and soil moisture applications by using remote sensing data from the NASA-ISRO Synthetic Aperture Radar (NISAR) mission (expected launch 2022). Participants included representatives from the international agriculture community that are key players in facilitating integration of Earth Observations into decision support workflows including US Federal Agencies, nonprofits, and private sector. They included scientists, technicians, and program managers with a responsibility for data acquisition and exploitation such as product development, delivery, and use, as well as capacity building. Discussions were held over two and a half days to convey the broader agriculture and soil moisture community information needs, the mission and procedures for various representative participants and programs involved in the delivery of geospatial products, and the capabilities and status of the NISAR mission. Case studies were presented to demonstrate the current state of practice in the use of SAR remote sensing for applications of direct importance for the agriculture and soil moisture communities. Eleven organizations presented their information requirements in response to a set of questions provided by the NASA team, then the NASA team responded by describing the degree to which NISAR could meet these requirements. Discussion ensued about needed data product specifications to increase utility (e.g., projection, latency, etc.), tools and capacity building.

The general findings of this workshop were that (a) NISAR observations will be particularly useful to the agriculture and soil moisture communities with information products of particular value to increase NISAR utility: soil moisture, crop classification, surface water extent/flood inundation, and crop yield; (b) providing data in a software-recognizable projection and resources for easy preprocessing of terrain corrections and georeferencing and multiple speckle filtering; (c) more discussions with the community are needed regarding calibration and validation of higher-level information products; (d) there is a need to increase SAR literacy and the most effective ways to reach the agriculture and soil moisture communities specifically; and (e) many in the agriculture and soil moisture communities must respond to international disaster charter requests, thus follow-up conversations should focus on how these communities could use NISAR data in response. It was noted that a 12-day repeat airborne campaign would improve understanding of how algorithms are affected by temporal variability; there are many lessons to be learned from what SMAP accomplished during SMAPVEX; and there are many existing programs that can be leveraged to provide field data for a cal/val campaign specific to the agriculture and soil moisture communities' needs. To integrate these findings and prepare the community before NISAR launches, it was recommended that there be a dedicated NISAR Agriculture and Soil Moisture Applications Working Group (as per the specifications in the NISAR Utilization Plan).

2 Overview

Monitoring and measurement from earth observing satellites have been a means for understanding the natural resources of our planet for over 40 years. However, in the last 10 years, with the development of innovative signal processing techniques, the ability to measure changes in moisture content and structure to the survey quality required by land managers opened a new frontier for the monitoring and assessment of agricultural lands from space. NASA's upcoming NISAR mission will be unique in providing comprehensive and frequent imaging of nearly all lands globally twice every twelve days with open access to the data. This is potentially a game-changer for planning and management of agriculture globally, particularly in areas with dense cloud cover or at high latitudes. The NISAR Agriculture and Soil Moisture Applications Workshop was held on June 26-28, 2018 at the USDA National Agricultural Library in Beltsville, Maryland with representative members from the broader agricultural community including non-profits, private, and government agencies to determine how to best leverage the NISAR mission for monitoring agricultural lands globally.

2.1 Workshop Objectives

The NISAR Agriculture and Soil Moisture Applications Workshop focused on four overarching objectives derived from input provided in the omnibus 2015 NISAR Applications Workshop. In the 2015 workshop NISAR received a recommendation to focus the workshops around different communities as each have very different experience levels with Synthetic Aperture Radar (SAR), community capabilities, and requirements. To meet these recommendations, NISAR worked with the USDA to tailor the objectives to:

1. Identify high-impact applications for integrating NISAR into Agriculture and Soil Moisture Applications. High impact was defined to be a function of relevance of the application to many organizations and agencies working with agricultural lands, feasibility of the NISAR observation and latency deliverables to meet application requirements, feasibility of the user community to ingest and use the data, and maturity of algorithms for producing information, value-added products (Data Level 3+) for operational deployment globally.
2. Develop a roadmap for the integration of SAR into agricultural land management decision support systems for the identified high-impact applications
3. Identify early engagers (analogous to "early adopters"; see the NISAR Utilization Plan) to help develop value-added information products (Data Level 3+), test application of the data in the decision-making context, and distribute to the broader agricultural land management community.
4. Identify partners for calibration and validation of NISAR Level 3+ information products, particularly those being developed by the project and distributed over calibration/validation sites.

2.2 Workshop Format

The two-and-a-half-day workshop was designed to meet the objectives, where the first day focused on identifying high impact applications and the second day focused on developing a road map and identifying early engagers. The last day was dedicated to the discussions (explained later?) on the NISAR Agriculture and Soil Moisture Applications Working Group.

2.2.1 Workshop – Day 1

On the morning of the first day, we had morning welcomes by both NASA and the US Department of Agriculture that included the respective agencies' missions, organizations, and an overview of the NISAR mission and descriptions of the algorithms being developed for forest biomass estimation and disturbance detection. Afterwards, the representative community members presented on their agency/organization mission, site descriptions of the lands of interest, information needs (variables, spatial and temporal resolutions and latencies), remote sensing capabilities and biggest challenges within their agency/organization. Specifically, participants answered the following questions:

- What is the mission of your organization? Does it have an advisory or policy-making role? Does it include routinely providing any data/information products, and if so what and to whom?
- Describe the lands and facilities, as appropriate to the NISAR mission, with which your agency/organization works. What are their extent, location, use or function (crops, fields, processing, etc.; US and globally, dependent on climate zones)?
- Does your organization have a requirement of routine monitoring? If yes, what particular feature or characteristic needs to be monitored? Examples: crop types or status, crop rotation (including fallow cycles), acreage, yield, soil moisture, etc. What are your latency requirements for routine surveillance (can differ by activity)? Over what time period does the surveillance occur? If you need a time series of information, how long would a single series be (season, years, decades)?
- Does your organization have a response mission in the event of a disaster or major disturbance? What are the types of disasters? What scale of disturbance requires urgent response? What primary information products do you rely on and what are their sources? What are your latency requirements for disaster response, mitigation, recovery?
- How are remote sensing data used in your decision support systems? If so, describe the type of data and applications. What is your organization's capability for integrating remote sensing data?
- What are the most challenging problems that you face where external monitoring could significantly improve your ability to meet your agency's objectives (e.g., enhance food security or facility security, product reliability?)
- If you could get information twice every 12 days, what specific information would be of highest value? Of high value? Difficult to obtain or currently unreliable?

After the individual presentations, an open discussion was held to clarify similarities and differences across agencies and organizations. This was followed by a response from the NISAR Science Team about commonalities that NISAR could address and the technical issues involved. For example, common Level 3 data products were identified, their needed and possible latencies discussed, as well as identifying a need for capacity building. The day concluded with a note from NASA Headquarters on what NISAR is funded to provide and a call for collaboration to fulfill additional needs.

2.2.2 Workshop – Day 2

The second day focused on developing a roadmap for integrating NISAR into the agriculture and soil moisture communities' decision support infrastructure, and identifying the potential for early engagement through an ad hoc working group. There were several presentations highlighting feasibility studies that used SAR data to produce value-added information products and integrate them into the decision-making context. These presentations were divided into two sub-sessions: algorithm developments and operational integration of remote sensing that specifically addressed a number of questions:

- What was the organization/decision-making context?
- What was the information gap?
- Why was SAR a good fit?
- What did the algorithm look like? Which band and frequency were used? How well did it perform?
- How was it integrated and tested in the decision-making context?
- What were the challenges or lessons learned about integrating SAR data into a local decision-making context? What worked? What didn't? Why didn't it?
- Is it something that will be sustained or augmented once L-band SAR from NISAR is made globally and publicly available? Can we possibly use this in other places (i.e., how extractable is it)?

This was followed by talks on the current resources available for early engagement with NISAR prior to and after launch, including big data, the cloud computing and storage, and current SAR data availability from other sensors. Then we discussed sector requirements and developed a plan for NISAR engagement with the community. The day concluded with three presentations from the NISAR Science Team on; 1) NISAR Calibration and Validation (cal/val) plans and needs; 2) the existing Joint Experiment for Crop Assessment and Monitoring (JECAM) field data; and 3) experiences of a SMAP mission cal/val partner. The community discussed further refining the NISAR cal/val plan and what would be needed to engage cal/val partners (e.g., what were the expectations of cal/val partners to the mission for return on investment of time and effort?). To end the day, Craig Dobson, the NASA NISAR Program Scientist, concluded with some final thoughts on next steps for the NISAR mission and the community.

2.2.3 Workshop - Day 3

On the final half-day of the workshop, several members of the community stayed to discuss the needs and available data to support a 12-day repeat airborne campaign in the southeastern US to support algorithm development and refinement in preparations for NISAR, as well as capacity building efforts. These discussions focused and formalized the need for the NISAR Agriculture and Soil Moisture Applications Working Group(s).

3 Mission Overview

3.1 Mission Design

The NASA–ISRO Synthetic Aperture Radar (NISAR) mission is a partnership between NASA and the Indian Space Research Organization (ISRO), currently scheduled to launch in early 2022 and to have a minimum mission lifetime of three years with consumables up to 15 years. The mission is optimized for studying hazards and global environmental change, specifically in support of ecosystem, cryosphere, and solid earth science. The satellite is designed to provide a detailed view of the Earth to observe and measure some of the most complex processes, including ecosystem disturbances, ice-sheet collapse, and natural hazards.

Table 1 – NISAR characteristics and capabilities.

NISAR Characteristic:	Enables:
L-band (24 cm wavelength)	Foliage penetration and interferometric persistence
S-band (12 cm wavelength)	Sensitivity to light vegetation
SweepSAR[1] technique with Imaging Swath > 240 km	Global data collection
Polarimetry (Single/Dual/Quad)	Surface characterization and biomass estimation
12-day exact repeat	Rapid Sampling
3 – 10 meters mode-dependent SAR resolution	Small-scale observations
3 years science operations (5 years consumables)	Time-series analysis
Pointing control < 273 arcseconds	Deformation interferometry
Orbit control < 350 meters	Deformation interferometry
> 30% observation duty cycle	Complete land/ice coverage
Left/Right pointing capability	Polar coverage, north and south

[1] SweepSAR is a technique to achieve wide swath at full resolution. See Section 4.7 for a more detailed description.

3.2 Mission Capabilities

NISAR will utilize two SAR instruments operating at different frequencies to study the Earth. NASA will provide an L-band SAR and ISRO will provide an S-band SAR. Table 1 shows some of the mission instrument and imaging parameters, and the kinds of measurements that they enable. NISAR's L-band radar instrument will provide all-weather, day/night imaging of nearly the entire land and ice masses of the Earth repeated 4-6 times per month considering both ascending and descending orbits, and the S-band instrument will provide additional coverage of India and parts of the polar regions. Depending upon the operating mode, NISAR's orbiting radar can image at resolutions of 3-50 meters, to identify and track subtle movement of the Earth's land and its sea ice, and even provide information about what is happening below the surface in areas where subsurface processes result in surface deformation. Regular and consistent repeat imagery can be used to detect small-scale changes before they are visible to the naked eye and to track dynamic changes as conditions evolve.

Table 2 – NISAR L-band and S-band radar modes, science targets, polarizations, pulse bandwidth (BW), pulse repetition frequency (PRF), pulse width (PW), and image swath width.

Science			Performance	
Primary Science Target	Freq Band	Polarization	BW (MHz)	Swath (km)
Background Land	L	DP HH/HV	20 + 5	242
Background Land Soil Moisture	L	QQ	20 + 5	242
Background Land Soil Moisture Hi Pwr	L	QQ	20 + 5	242
Land Ice	L	SP HH	80	121
Land Ice Low Res	L	SP HH	40 + 5	242
Low Data Rate Study Mod SinglePol	L	SP HH	20 + 5	242
Sea Ice Dynamics	L	SP VV	5	242
Open Ocean	L	QD HH/VV	5 + 5	242
India Land Characterization	L	DP VV/VH	20 + 5	242
Urban Areas, Himalayas	L	DP HH/HV	40 + 5	242
Urban Areas, Himalayas SM	L	QQ	40 + 5	242
Urban Areas, Himalayas SM Hi Pwr	L	QQ	40 + 5	242
US Agriculture, India Agriculture	L	QP HH/HV/VH/VV	40 + 5	242
US Agriculture, India Agriculture Low Res	L	QP HH/HV/VH/VV	20 + 5	242
Experimental CP mode	L	CP RH/RV	20 + 20	242
Experimental QQ mode	L	QQ	20 + 20	242
Experimental SP mode	L	SP HH	80	242
ISRO Ice/Sea-Ice	L	DP VV/VH	5	242
ISRO Ice/Sea-Ice - alternate	L	QD HH/VV	5	242
Solid Earth/Ice/Veg/Coast/Bathymetry	S	QQ	37.5	244
Ecosystem/Coastal Ocean/Cryosphere	S	DP HH/HV	10	244
Agriculture/Sea-Ice	S	CP RH/RV	25	244
Glacial Ice-High Res	S	CP RH/RV	37.5	244
New Mode	S	DP HH/HV	37.5	244
Deformation	S	SP HH (or SP VV)	25	244
Deformation-Max Res	S	SP HH (or SP VV)	75	244

Table 2 shows the NISAR acquisition modes for the L-band and S-band antennas, along with parameters specific to each mode. The ground resolution in the cross-track direction is set by the pulse bandwidth (BW), and is 3/6/12 or 50 m for 80/40/20 or 5 MHz, respectively. The ground resolution in the along-track direction is 8 m for all modes. The instruments can operate in single-polarization (SP) HH or VV (the first letter indicates the transmit polarization and the second indicates the receive polarization, either horizontal or vertical); dual-polarization (DP) HH/HVor VV/VH; co-polarization (QD) HH/VV; quad-polarization (QP) HH/HV/VV/VH, or quasi-quad polarization (QQ) (HH/HV/VV/VH with slightly different frequency H and V transmit). The mode selected depends upon the science target for a given location (see section 3.3). The L-band instrument can also operate in Compact Polarimetry (CP) mode transmitting right circular polarization (R), but there are no plans for using that mode operationally.

3.3 Current Mission Observation Plan

The current observation plan is shown in Figure 1. This near-final observing plan will be dominated by L-band SAR HH/HV observations with a 12m x 8m spatial resolution and a 12-day repeat interval across most of the land area outside of the polar regions and Greenland. A funding augmentation currently underway will provide 6m x 8m spatial resolution data over North America lands. Revisions of the observation plan are under consideration, but not finalized, to limit the acquired data volume to the downlink capacity through a combination of increased temporal repeat intervals or single polarization acquisitions over low priority areas. This reduction is driven by NISAR's primary data volume limitations of: 1) a maximum data downlink volume constraint, and 2) thermal constraints for several instruments on the spacecraft. At this time, the former sets the upper limit of 26 Tbits/day (Tb/d) (to become 35 Tb/d with the augmentation), with the limitation in the ground segment capability, not in the satellite hardware. The data downlink constraint is set by the number of ground stations that NISAR anticipates using and their throughput limits (Figure 2). This is important because the instrument maturity is at the stage where design of the hardware to be launched cannot be changed without significant impact to mission cost and schedule. In contrast, changes to the ground segment, including downlink capability at this point in time would not significantly impact mission schedule, though would add cost for downlink, transfer, processing, and storage for added downlinked data volumes.

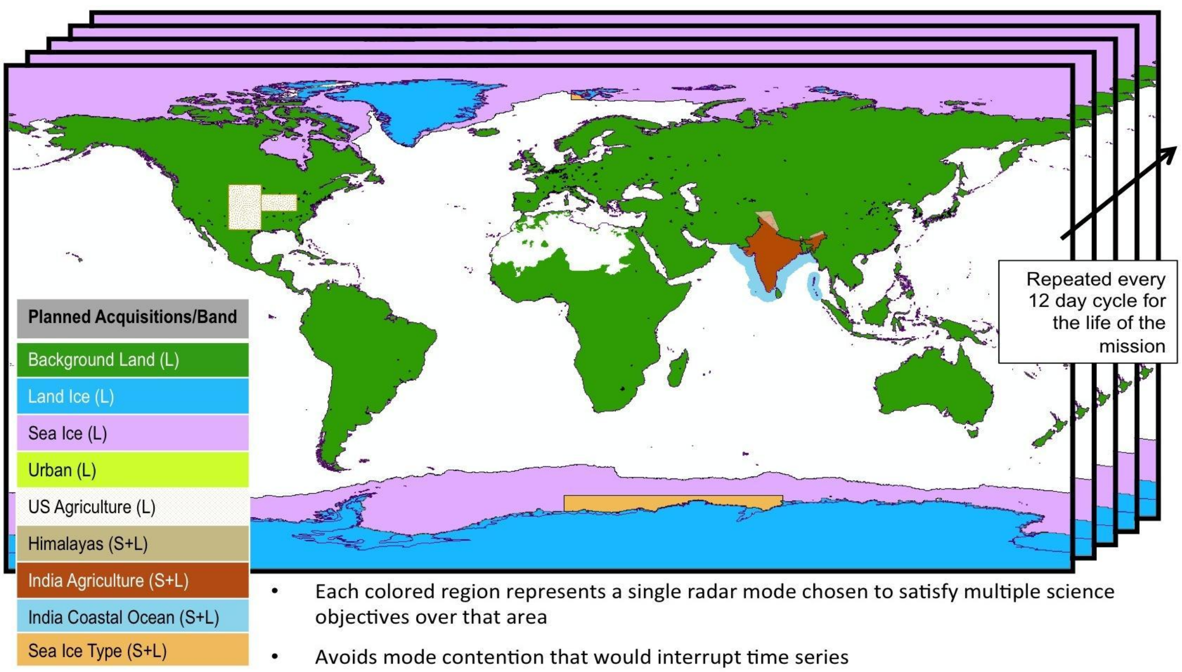

Figure 1 – Near-final mission observation plan. Revisions that increase data volume will require additional ground stations for increased downlink capability.

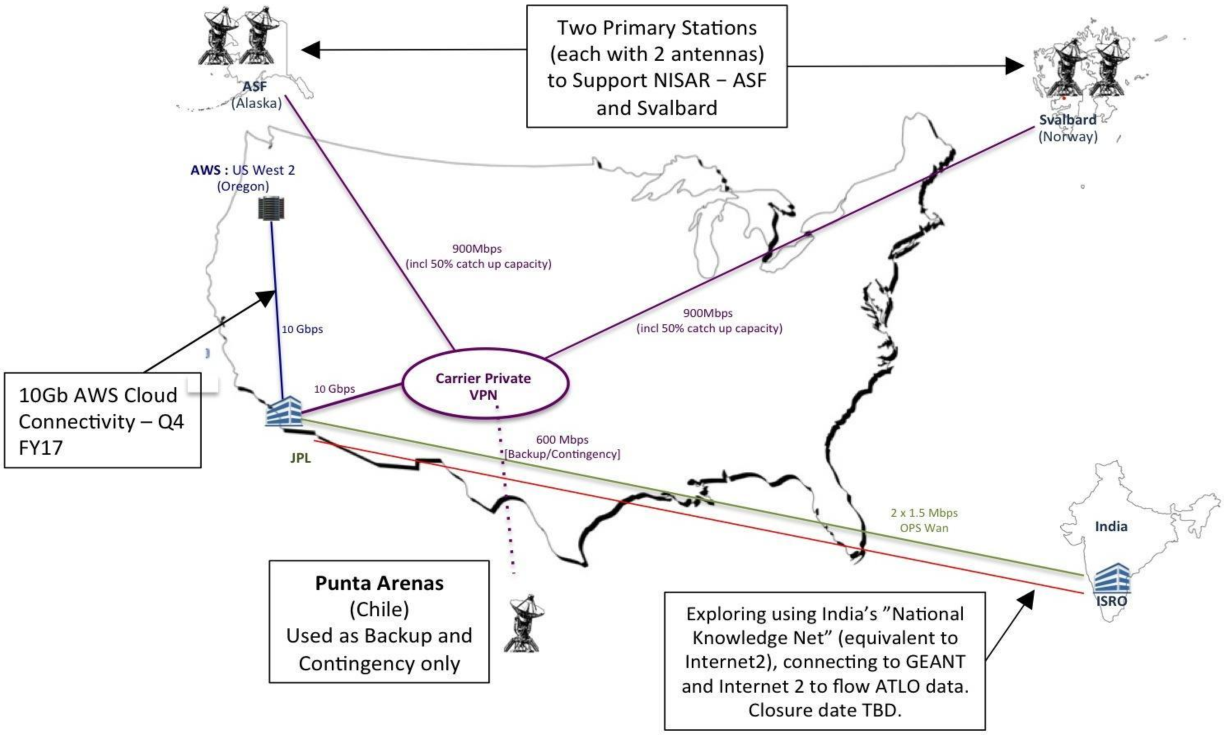

Figure 2 – Current ground station network envisioned for NISAR. Data transfer between the downlink stations and the processing centers is also shown. Processing will be done at ISRO and at a center in Oregon, with U.S. transfer funneling through JPL. A funding augmentation could provide an additional downlink station within the U.S.

Table 3 – Near-final list of the standard NISAR data products to be delivered within 2 days of acquisition. The range-doppler SLC, a product that is posted in the radar reference frame (i.e., not geocoded), is the base-level (Level 1, or L-1) product from which all others are derived.

Product	Scope	Description
Range-Doppler Single Look Complex (SLC)	Global and all channels	Standard L1 product that will be used to generate all higher-level products
Geocoded SLC (GSLC)	Global and all channels	Geocoded SLC product using medium orbit ephemeris (MOE) and a DEM.
Geocoded Nearest-Time Interferogram (GIFG)	Everywhere. Nearest pair in time and co-pol channels only.	Geocoded interferogram with interferometric phase and coherence.
Geocoded Nearest-Time Unwrapped Interferogram (GUNW)	Everywhere. Nearest pair in time and co-pol channels only.	Geocoded multi-looked unwrapped differential Interferogram.
Polarimetric Covariance Matrix (COV)	Everywhere. All channels. All pols including single pol.	Backscatter product in Range-Doppler coordinates.
Geocoded Polarimetric Covariance Matrix (GCOV)	Everywhere. All channels. All pols including single pol.	Geocoded backscatter product in Range-Doppler coordinates.

3.4 NISAR Products and Latency

All NISAR data will be processed by the NISAR project team into a set of standard polarimetric (PolSAR) image and interferometric SAR (InSAR) data products (Table 3). These data products are expected to be available 24-48 hours after observation. The standard products include polarization-dependent images, interferograms, and interferometric coherence. The latter two can be used for change detection and for measurement of surface displacement.

In addition to the standard acquisition and processing stream, an urgent response capability will be available through which lower latency products can be made available. The details have not yet been worked out, but the goal is to be able to deliver the products listed in Table 2 with less than a 12-hour latency (goal of 5 hours) following acquisition when urgent response acquisitions are initiated. The time between when an event occurs and when the next NISAR image of the area can be made depends upon when the next pass of the satellite over the event location occurs and varies within the maximum 6-day period for coverage considering that the area could be imaged on either ascending or descending orbits.

4 NISAR's Applicability to Agriculture and Soil Moisture for Land Management

As population increases, agriculture and food security have become topics of global importance. Land conversion coupled with extreme weather events can impact production, prices, and livelihoods. Given that billions of people depend on agriculture for their livelihood and agriculture is an important policy driver, NASA has supported using Earth Observations for monitoring agriculture for decades. Traditionally, the research and decision support tools have focused on using optical data such as Landsat and MODIS, while use of Synthetic Aperture Radar (SAR) for agricultural monitoring has lagged. With the launch of Sentinel-1A & B, and the planned launch of the NISAR mission, new opportunities exist with operational, open access radar data streams.

Since the 1970s, projects such as the Large Area Crop Inventory Experiment (LACIE) and Agricultural and Resources Inventory Surveys Through Aerospace Remote Sensing (AgRISTARS) have leveraged spaceborne Earth observations (EO) to map crop type and extent. These early works have evolved into many national scale decision support tools that largely leverage moderate (25-30m) and coarse (250m-1km) resolution optical data for delineating and mapping croplands and condition. For example, in the US, the Department of Agriculture, National Agricultural Statistics Service (USDA-NASS) generates annually the Cropland Data Layer (CDL). In the past five years, CDL inputs have focused on using optical satellite data, namely Landsat along with inputs from Deimos-1, UK-Disaster Monitoring Constellation (DMC), and Sentinel-2 to generate nominal 30m pixel resolution maps of crop type. Within the season they are used internally by NASS to supplement planted area survey information but after the season they are released to the public and as such have been used in a variety of applications.

Historically, SAR applications for crop monitoring have been much fewer relative to optical data. The reasons for this include limited data availability; lack of consistent, large-area operational acquisition strategies at appropriate scales; poor quality digital elevation models required for processing; complex data structures relative to optical data; and lack of standardized workflows. Even the more progressive data acquisition plans have not met the requirements for operational monitoring of crop landscapes.

When crops and agricultural fields are under stress from flooding, fire or drought, NISAR data can be used across the entire disaster management cycle, which encompasses mitigation and preparedness before a disaster occurs, the disaster response phase, and the recovery post-disaster. Active microwave systems, such as NISAR, have the advantage of being able to image through clouds and smoke, independent of solar illumination. Furthermore, because the NISAR instrument operates at L-band, microwave observations can penetrate foliage to be sensitive to ground conditions that support agricultural fields. Because repeated NISAR images (same orbit and sensor look direction) will be acquired at 12-day intervals, a dependable time series of data can be established to observe crops throughout their growing period and afterward. This will open up new opportunities in crop classification and monitoring with tools that heretofore have not been readily available.

During flooding, NISAR data can be used to identify flood extent, either using image amplitude products, which are based on the fact that standing water appears radar-dark, or using interferometric change detection to identify change. Similar methods have been shown to work in identifying fire burn areas, ice flows, or other ground disturbance processes.

5 Agriculture and Soil Moisture Applications Agency/Organization Overview

This workshop was focused on understanding the information requirements of representative agencies and organizations that can help bridge the gap between the low-level data that NASA provides and the higher-level information needed by forest land managers. There were two opening talks, one presented by a US Department of Agriculture (USDA) National Program Leader within ARS, and one by the USDA Remote Sensing Coordinator who leads the Satellite Needs Working Group. There were subsequent talks by each of the relevant agency departments and organizations participating, specifically:

- USDA National Agricultural Statistics Services (NASS)
- USDA Foreign Agricultural Service (FAS)
- USDA Agricultural Research Service (ARS)
- Agriculture and Agri-food Canada (AAFC)
- National Drought Mitigation Center (NDMC)
- Climate Corporation (Monsanto Subsidiary)
- DuPont Pioneer
- Applied Geosolutions
- Group on Earth Observations Global Agriculture Monitoring (GEOGLAM) and the NASA Harvest Consortium (formerly EOFSAC)
- Winrock International
- US Geological Survey (USGS) Famine Early Warning System Network (FEWS NET)

Each agency/organization was asked to make a presentation addressing the questions that were sent by the NASA team (Section 2.2.1) followed by discussion.

5.1 USDA Programmatic Overview

The US Department of Agriculture (USDA) provides federal leadership on food, agriculture, natural resources, rural development, nutrition, and related issues based on sound public policy, the best available science, and efficient management. Within USDA, agencies are organized by function and to allow for proper communication on topic areas of interest, including both research and operational agencies. The leading agencies for NISAR interaction are the Agricultural Research Service (ARS), the National Agricultural Statistics Service (NASS), and the Foreign Agricultural Service (FAS). These agencies can serve as the liaisons to other agencies that may make use of NISAR data.

5.2 USDA Participation in the Satellite Needs Working Group

The US Group on Earth Observations (USGEO) Satellite Needs Working Group (SNWG) process provides the first-ever whole-of-government approach to identifying desired satellite products across the civilian agencies and communicating this information to NASA. In 2016 NASA was made the agency responsible for developing all US Government civilian Earth-observing satellites, with the exception of weather satellites, which continue to be funded and managed by NOAA. This framework for satellite responsibilities was intended to address:

- Challenges in transitioning experimental observations into sustained observations
- Uncertainty over whether existing satellite measurements would be continued

USGEO, an interagency group with 13 agencies, was tasked with developing a process by which agencies would provide inputs on their desired satellite measurements/products to NASA. And as a result, a SNWG was created. The SNWG supports a process every 2 years by which Federal departments and agencies can communicate their desired satellite-based Earth observation data/information products to NASA and potentially other providers of satellite observations. NASA will take these inputs into consideration when developing its future plans and budgets.

In 2016, NASA received 187 product requests from 17 Federal government departments and agencies. The Earth Science Division (ESD) assembled 35 subject matter experts analyzing/clarifying the requests and determining the feasibility of generating and providing the desired information products. This process focused NASA's discussions on creative ways to meet the needs of the SNWG and served as a tool to spread awareness to other agencies about NASA's existing high impact products.

The FY19 Budget includes augmented funding of NASA to support additional capability for the NISAR mission in response to needs identified in the Satellite Needs Survey Process. The requested funding will support additional ground stations and communication links for NISAR data, which in turn will generate additional data, including soil moisture and natural hazard data, that will be of value to multiple federal agencies as well as the science community. The NISAR mission will provide a detailed view of the Earth using advanced dual frequency synthetic aperture radar imaging.

The USDA collaborations will provide increased communication and understanding among the agencies that use satellite data and NASA. This also serves as an opportunity for synergy. During the process Agency Technical Point of Contacts will be identified.

5.3 USDA National Agricultural Statistics Services (NASS)

The USDA NASS mission provides timely, accurate and useful statistics in service to the US Department of Agriculture (USDA). It is the domestic statistical gathering agency of USDA. Some of these reports are disseminated to the public (e.g., production agriculture) at weekly, monthly, quarterly, annual and quinquennial time intervals.

NASS covers the US domestic agricultural lands. They conduct surveys and census reports at national, state, county, and watershed scales. They have gridded geospatial products (e.g., National Cropland Data Layer) that are designed to provide information at the field scale nationally. They track 109 different crops.

NASS routine monitoring includes crop area, crop yield, vegetation condition, soil moisture, and ad-hoc information requests of agricultural flooding and inundation impacts. Crop area is monitored at 30 m pixel resolution at least every week depending on the availability of cloud-free data. Monthly reporting for crop area starts in June and goes through year end. This information is available through CropScape. Crop yield is monitored at 250 m pixel resolution as a weekly composite with monthly reporting starting in August. Vegetation condition is monitored at 250 m pixel resolution at daily, weekly, and bi-weekly intervals throughout the growing season with VegScape. Soil moisture is monitored at daily and weekly time intervals throughout the growing season.

NASS disaster response mandate focuses on providing updated statistics in the event of drought, flood, early season frost, and early season snowfall. Disaster assessments during floods focus on inundation impacts are to be provided to USDA and the Federal Emergency Management Agency (FEMA) within 48 hours of storm peak. At present, NASS relies on Sentinel-1 to map crop inundation in near real-time.

The remote sensing capability of NASS includes producing maps of monthly area and yield indicators to the NASS Agricultural Statistics Board through the Cropland Data Layer. Inputs to this data layer are DMC DELMOS-1, UK2, Resourcesat-2, Sentinel-2 and Landsat-8, the 2011 National Land Cover Database (NLCD) and derivative products, Farm Service Agency: Common Land Unit data, and supplemental ground reference data. There are plans to integrate SMAP soil moisture products with the AgroClimate Decision Support System that delivers the enhanced Crop Progress and Condition updates. Additionally, NASS is working to categorize SMAP products into the qualitative categories used in cropland statistical reporting: very short, short, adequate, and surplus. Lastly, NASS is working on developing near real time (NRT) disaster assessments using remote sensing data.

The biggest challenges for NASS include lack of frequent temporal observations and data latency, early season crop emergence and identification, estimating crop yield and drought/disease, and rapid response to disasters for estimating crop area affected and soil moisture.

The value of NISAR will be in providing high resolution imagery, as well as derived top- and root-zone soil moisture nationally. This data will be complementary to Sentinel-1 A/B, and can be used for its rapid disaster response capability, and the ability to derive products such as crop-area mapping, soil moisture by crop type, early season crop emergence and identification, as well as crop phenological stage/vegetation reproductive phases.

5.4 USDA Foreign Agricultural Service (FAS)

The USDA FAS Office of Global Analysis mission is to maintain and operate the USDA Economic Information System providing the official US government estimates of World Agricultural Production. Specifically, FAS provides market intelligence along with 100 US Embassy and Consulates and a global network attaché.

FAS lands of interest include global agricultural lands. These lands include agricultural fields with edges that are forests or open in temperate and tropical zones, both of which can have dense cloud cover. FAS routine monitoring includes data and information products of monthly area, yield and production estimates for 18 commodity crops across 166 countries (~1,209 Country-Crop pairs). Products include crop type, rotation, health, growth stage, production area, yield, and soil moisture. FAS also provides the Crop Explorer with information on weather, soil moisture, drought severity, vegetation index, satellite imagery, crop calendars, and crop distribution maps. These products are produced by the USDA FAS International Production and Assessment Division. Geospatial data has to be recent, easy to use and relevant. Latency of analysis-ready products must be within 24-72 hours after observation. The critical time period to ensure product use is to have the products in hand by the last week of each month so that they can be analyzed and discussed in the first week of the following month. Data acquisition coverage must be global and routine to provide consistency with weekly (or better) observation time-series data from 2000-present. Analogue comparison datasets stretch back 30+ years.

FAS disaster response mandate is for the International Production and Assessment Division to respond with estimates of disaster assessment and impact to crop area, yield, and production. Disasters include floods, hurricanes/typhoons, tsunamis, hail storms, droughts, and flash droughts. To provide these assessments FAS has partnered with the Pacific Disaster Center for disaster alerts who provide hourly updates. The primary information products for disasters include precipitation from USAF, NOAA, NASA, WMO, and CHIRPS, storm forecast track from the Pacific Disaster Center, and wind speeds from TAOS. The latency for these products is within hours to days for the first report and monthly for impact to crop area, yield and production.

The remote sensing capability of FAS is high as they incorporate data from MODIS Terra and Aqua, VIIRS, TRMM, GPM, SMOS, Sentinel-2, Landsat-8, SSM/I, IIR-19, Worldview-1 and 2, Sentinel-1, RADARSAT-2, and Jason-2 and 3.

The biggest challenges for FAS are with the mid-resolution optical imagers, high-resolution optical imagers, SAR, and collocating with field data as well as in assessing impacts to crop area, yield and production from meteorological events and tracking policy changes. The challenges with mid-resolution imagers (Landsat-8/Sentinel-2) present moderate hurdles that include a transition plan between the two and securing funding for a harmonized Landsat-Sentinel product. The challenges of high-resolution optical imagers and SAR present significant hurdles for the agency including tasking, access to archives, funding for use, and development of analysis-ready data. The challenges with field data location present a moderate hurdle in providing analysis-ready data.

The value of NISAR will be in providing data about floods and crop type. The value to USDA FAS will be in providing analysis ready data of flood extent, progression, and duration. Importance of providing this information is the need to compare to previous flood events. Not only does USDA FAS need to map flooding, but they also need to understand this in the context of crop types. Crop Type mapping can be particularly challenging in areas with persistent cloud cover.

5.5 USDA Agricultural Research Service (ARS)

The USDA ARS mission is to conduct research and to develop, and transfer solutions to agricultural problems of national priority and provide information access and dissemination. Applications of interest include assurance of high-quality, safe food and other agricultural products; assessment of nutritional needs of Americans; a sustainable and competitive agricultural economy; enhancement of the natural resource base and environment; economic opportunities for rural citizens, communities and society as a whole; and infrastructure necessary to create and maintain a diversified workplace.

ARS researchers issues on both international and domestic lands with 90+ research locations, including overseas laboratories. USDA ARS has a Fiscal Year budget of $1.2 billion that supports 690 research projects within 15 National Programs supporting 2,000 scientists and post-doctorate candidates and 6,000 support staff.

The ARS routine monitoring is conducted as part of the Long-Term Agro-ecosystem Research (LTAR) program. LTAR monitors meteorological data (Flux towers), crop types and status including land cover mapping and drought monitoring capability, yield, soil moisture (8+ networks), and additional measurements as needed. NRT monitoring data are available within collaborative research agreements. ARS disaster response mandate is limited to investigating animal disease outbreaks and providing inspection services at ports of entry to the US Animal and Plant Health Services (APHS).

The remote sensing capability of the USDA ARS is high and research with this data is critical for estimating yield, soil moisture and drought monitoring. ARS has developed a well-established set of decision support systems for use by “action” agencies (e.g., NASS and FAS).

The biggest challenges for ARS include monitoring inaccessible locations, regular monitoring in cloud-covered regions, crop forecasting, observing soil moisture status, and flood risk modeling. The value of NISAR will be in providing high-spatial resolution data on a regular basis that can be used to derive soil moisture and yield/biomass estimates at a management scale.

5.6 Agriculture and Agri-food Canada (AAFC)

AAFC provides science, data, maps, and reports using geospatial information on the agriculture, climate, land use, and soil resources of Canada to support sustainability and resiliency in agricultural landscapes in Canada. The Agroclimate, Geomatics and Earth Observation (ACGEO) division takes promising research, and carries out further applications development in order to deliver on operational reporting. As such, ACGEO works closely with Earth observation scientists within AAFC’s Science and Technology Branch. End users are internal and external to the division. The primary focus is on serving internal needs to the agriculture sector (i.e., providing information on what is growing where, how weather is impacting crop growth and yields, soil properties, and land management) to support program development, policy, implementation, and market forecasting.

Canada's agricultural areas are concentrated in the southern regions of the country. Agriculture is responsible for 7% of GDP and 12% of employment. Most crops are single season and rain-fed. Top crop commodities include canola, wheat (spring, durum, winter), corn, soybean, barley, lentils/dry beans, potato, localized fruit and vegetable production (British Colombia interior and Niagara). Corn and soybean production is largely concentrated in the East, but it is growing as a portion of production in the Canadian Prairies.

AAFC routine monitoring includes delivering data, maps, reports and geospatial tools. This work results in data, products and scientific publications for numerous applications including: 1) agroclimate: climate-related risk and vegetation condition maps and reports on a weekly, biweekly and monthly basis; 2) drought assessments and yield forecasts on a monthly basis; 3) crop inventory, seasonal summary reports and livestock tax recommendations on an annual and semi-annual basis; and 4) soils maps, land suitability ratings, and sustainability metrics that are updated as technology and methods advance, new data sets become available or as conditions change. All data is made available through an open data repository. Maps are made available through static map selection tools, dynamic geospatial web applications, and embedded in reports (static and online interactive).

AAFC disaster response mandate includes Business Risk Management in partnership with provincial governments. Assessment covers events such as drought, flooding/excess moisture, sudden drops in market demand or low prices, and disease infestation. ACGEO produces biweekly memos on climate related risks to the Canadian Minister of Agriculture to support budgeting decisions and monthly crop production forecasts used by Market and Industry Services for economic outlook reports. AAFC will use the best available data (weather stations, satellite remote sensing, crowd sourcing, media, weather forecasts) with an aim for ~24 hour latency.

The remote sensing capability of AAFC uses optical satellite data and C-band radar to create the annual crop inventory (30 m pixel resolution), daily to weekly products of soil moisture (from field scale to regional scales), vegetation health (250 m), and evaporative stress (1-3 km), and the decadal land use and land cover change product (30 m). For the last 3 decades, AAFC scientists have conducted extensive research into the use of multi-frequency (X-, C- and L-band) SAR for crop classification, soil moisture retrieval and mapping land management and tillage. AAFC is also leading the international JECAM SAR inter-comparison research project, whereby C-band SAR is being collected over 25 agricultural sites around the world with X- and L-band SAR collected for a subset of these sites.

The biggest challenges for AAFC are related to developing resilient agriculture systems in the face of a changing climate. To support this, AAFC needs better information at field scales to evaluate how management practices can mitigate risk. Also, AAFC needs better geospatial data to support the evaluation of different best management practices and to scale the research findings on these practices beyond individual field plots. Lastly, a challenge for AAFC are data gaps for mapping soil properties, high resolution crop yield, disease/pest risk, and harvest status, and in-season crop identification.

The value of NISAR will be in improving the annual crop inventory map, field scale excess soil moisture estimates, and yield prediction. AAFC research has demonstrated a clear benefit of integrating multi-frequency SAR for monitoring crops. For the annual crop inventory, NISAR will provide improved latency as it can be used to create early season maps and improved accuracy in cloudy regions for certain crops. L-band is also a preferred frequency (relative to C-band) for soil moisture retrieval given its greater penetration and reduced impact of roughness (at scales typical of agricultural field). For yield predictions, the current optical and passive microwave used by AAFC results in coarse spatial resolution soil moisture and vegetation condition estimates, so the higher spatial resolution from NISAR for soil moisture estimation will improve downscaled forecasts of crop yield.

5.7 National Drought Mitigation Center (NDMC)

The NDMC mission is to help people and institutions develop and implement measures to reduce societal vulnerability to drought, stressing preparedness and risk management rather than crisis management. Drought monitoring and early warning systems are a key component of the NDMC with information being used for planning and disaster response decisions at national, regional, state and local levels. The NDMC supports several national monitoring systems and development of new monitoring tools including the U.S. Drought Monitor (USDM), North American Drought Monitor (NADM), Vegetation Drought Response Index (VegDRI), and Quick Drought Response Index (Quick DRI).

The NDMC lands cover the United States, thus tools are national in extent and characterize 'sub-county' and landscape-level drought patterns. The USDM covers the continental US (CONUS), Alaska, Hawaii and Puerto Rico and monitors all areas. VegDRI and QuickDRI cover CONUS and focuses on federal lands.

NDMC routine monitoring includes regularly distributed drought monitoring maps from USDM, VegDRI and QuickDRI. USDM is mandated in the Farm bill as an eligibility trigger for drought disaster assistance; trigger definition varies by region, state, local, and tribal drought plans. USDM reports both agricultural (vegetation stress) and hydrologic drought with a nominal spatial resolution of 12 km x 12 km every week on Thursdays, year-round. Latency is within 24 hours of the last input observation of vegetation health, soil moisture, surface and ground water, precipitation and impacts. VegDRI and QuickDRI do not have formal monitoring requirements, but applications that do have come to rely on input from these systems. VegDRI is a composite drought index mapping drought-related vegetation stress. QuickDRI is a composite drought indicator monitoring landscape-level dryness. Both VegDRI and QuickDRI provide weekly maps on Mondays, year-round. The latency is within 24 hours of the last input observations of soil moisture, vegetation health, evapotranspiration, and precipitation. The final products are provided at nominal 1 km x 1 km spatial resolution.

NDMC does not formally have a disaster response mandate, however information produced by NDMC is used by other federal, state, and local organizations that do have a drought response mandate. These agencies have come to rely on operational production of NDMC products that is routinely released on an established time schedule.

The remote sensing capability of the NDMC is high as they have been integrating satellite remote sensing data since the early 2000s. Catalysts for NDMC to integrate new observations include new satellite sensors and types of observations, an extended 10+ year historical image data record, advancements in modelling and statistical analyses, and improved computing capabilities. Some satellite data that has been ingested include GRACE, SMAP and AIRS.

The biggest challenges for NDMC include obtaining information on root zone soil moisture, distinguishing which soil moisture products to use, and determining the best method for using the relatively short remote sensing records for drought anomaly detection. At present root zone soil moisture estimates are limited as there are spatial gaps from in situ measurements and are reliant on the use of models. Progress is being made with GRACE, SMOS and SMAP. Although there are a number of different soil moisture datasets, the challenge for NDMC is how these datasets are similar, how they differ, what depth(s) and conditions they represent, the latency of the products and the continuity of the products through time. Soil moisture observations are available, but how these relate to traditional indicators of drought that rely on 20-30 years of historical record is unclear. These shorter time-series (~10 years) might be appropriate as climate changes and the emerging non-stationarity of climate observations, but this is an area of research.

The value of NISAR will be in augmenting the existing soil moisture observation record. Currently NDMC is using soil moisture estimates from in situ (from various networks with variable spatial density and quality), modeled NLDAS, GRACE and SMAP. In particular, NDMC is interested in the ability of NISAR to provide root-zone soil moisture estimates at weekly time intervals.

5.8 Climate Corporation (Monsanto Subsidiary)

The Climate Corporation mission is to help all the world's farmers sustainably increase productivity with digital tools. There are six focus areas for research and development in fertility, seeds and planting, field insights, weather, measurements, and data connectivity and platforms.

Climate Corporation advances their mission through global Research and Development pipeline on agricultural lands in the United States, Canada, Europe and South America.

Climate Corporation does not conduct routine monitoring.

Climate Corporation does not have a disaster response mandate.

The remote sensing capability of the Climate Corporation is high as they provide a digital agriculture platform with information on fertility (e.g., Nitrogen, Potassium and Phosphorus concentrations), seed scripting, field health (e.g., disease diagnosis and vulnerability, stress, yield), and weather. The platform aggregates field scale measurements on maps and enables third-party data integration and APIs. This is a platform for third-party collaboration.

The biggest challenges for Climate Corporation are in the trades between spatial resolution and frequency of observation, data quality, producing an image processing pipeline and fusing different datasets.

The value of NISAR to Climate Corporation will be in providing better characterization of agricultural environmental variables, better capability for monitoring crop condition and identifying yield stressors, and collaborations with the SAR community.

5.9 DuPont Pioneer

DuPont Pioneer is a commercial company that provides crop protection and digital services to customers.

The DuPont Pioneer lands cover breeding research fields, seed production fields and grower farm fields. There are 4000 researchers at 100 research sites in 25 countries and 6 continents (all but Antarctica).

DuPont Pioneer routine monitoring includes crop productivity. DuPont aggregates real-time data from ~150 private sector and ~15 public sector satellites and overlays field boundaries and crop classification data layers to generate a crop health index at a granular level at the scale of a field. Dupont also produces a multi-satellite-data-fused product of real-time plant growth monitoring. Lastly, Dupont provides a map of the 10-year average predicted corn yield.

DuPont Pioneer does not have a disaster response mandate.

The remote sensing capability of the DuPont Pioneer is high as they aggregate real-time data from ~150 private sector and ~15 public sector satellites including optical and SAR data (i.e., Sentinel-1). DuPont produces crop productivity maps, delineates crop boundaries, classifies different crops, and characterizes specific crop growth curves.

The biggest challenges for DuPont Pioneer are cloud masking and uneven availability of SAR data from Sentinel-1, which makes extrapolation difficult.

The value of NISAR for DuPont Pioneer will be in providing time series of L-band backscatter to enhance crop classification and using polarimetric information to reliably quantify crop physiology at field scale.

5.10 Applied Geosolutions

The Applied Geosolutions is a commercial company that develops and operates SAR algorithms and Measurement, Reporting, and Verification (MRV) platforms for agriculture, water and forest applications.

Applied Geosolutions studies agricultural production hot spots (CONUS corn, soy, wheat belt), rice across S/SE Asia, and many dense small holder regions where food production exists.

Applied Geosolutions routine monitoring includes providing operational and systematic information for seasonal crop applications (e.g., soil moisture, crop classification, and inundation mapping) through robust, automated decision support systems. Applied Geosolutions provides information in near-real time (NRT; latency within 12-24 hours) at the field scale. In general, Applied Geosolutions relies on baseline time series of a few years to provide additional value through techniques that examine deviations from patterns and trends.

Applied Geosolutions does not have a disaster response mandate.

The remote sensing capability of the Applied Geosolutions is high as their primary focus is on operational use of SAR data.

The biggest challenges for Applied Geosolutions are in getting access to wide area and operational polarimetric SAR consistently throughout the year especially in the early growing stages for rice.

The value of NISAR for Applied Geosolutions will be in providing systematic, large-area L-band SAR data for monitoring. Applied Geosolutions recognizes that the routine overpass of NISAR providing high-resolution data will enable aggregating to moderate spatial resolution for field scale decision making, while also providing the high temporal frequency observations necessary for monitoring agricultural decision making. Applied Geosolutions will find additional value in quad-pol SAR data to help with early stage rice field classification when the fields are inundated, and in the ability to use L- and S-band NISAR data with C-band radar data.

5.11 The NASA Harvest Consortium (formerly the Earth Observations for Food Security and Agriculture Consortium (EOFSAC))

The Group on Earth Observations Global Agricultural Monitoring (GEOGLAM) Initiative was launched in Paris (June 2011) by the Group of Twenty (G20) Agriculture Ministers in order to strengthen the international community's capacity to utilize Earth observations. The intent of these observations is to produce and disseminate relevant information on agricultural production at national, regional, and global scales. The NASA Harvest Consortium is NASA's major contribution to GEOGLAM. Harvest's mission is to advance the use of Earth observations for enhanced food security and improved agricultural practices, especially for humanitarian pursuits, economic progress, resilience and sustainability. Harvest aims to advance the state of science of Earth observations, including moving existing activities to higher application readiness levels and increase the adoption of Earth observations by decision and policy makers. Specifically, Harvest aims to expand the number of applications developed, tested, and (if successful) transferred to the broader agricultural community related to food security. Harvest will do this by enhancing awareness of upcoming Earth observation satellite missions with value for agricultural decision support. Harvest will highlight and demonstrate real-world socioeconomic benefits of Earth Observations, identify opportunities and topics for future investigations, advance communication of the benefits of Earth science and observations, connect Earth observation and science communities with Food Security and Agriculture communities, and respond with agility to changing priorities.

Harvest has activities on both US and international lands. US domestic lands are owned and managed by federal agencies, state agencies, and private sector holders. Harevst's international efforts are currently focusing on East Africa (Uganda, Kenya, Tanzania, Rwanda, ICPAC/IGAD), Latin America (Aregentina, Brazil, Mexico and Chile), and Southeast Asia (Thailand, Vietnam, and Philippines). International efforts also include collaborations with the International Grains Council

(IGC) that provides quantitative production indicators and G20 Agricultural Market Information System (AMIS) that provides crop condition assessments internationally.

Routine monitoring by Harvest and GEOGLAM partners, includes crop area outlooks, agriculture crop type classification maps, area estimates, monthly bulletins and early warnings of crop conditions and growth, yield forecasts, production estimates, vulnerability reports, and international market reports. The Crop Monitors can be found at https://cropmonitor.org. A data portal provides monthly maps of crop condition as quick and easy to interpret information oriented for economists and policy communities. Some countries have adopted national versions of the crop monitor e.g. e.g. Tanzania and Uganda.

The disaster response mandate of GEOGLAM is to provide forecasts and early warning of crop conditions and crop yields. The remote sensing capability of Harvest is high, as their primary focus is on integrating Earth observations into operational workflows. Optical data have been widely used by the community for a long time, but there is an increasing interest in SAR data from the International Agricultural Monitoring Community of Practice. In particular, the community is using SAR data for estimating soil moisture from ALOS-2 PALSAR and Sentinel-1. Harvest is also showing promising results for using microwave and optical time series together.

One of the biggest challenges for GEOGLAM and Harvest is to manage expectations of users particularly with respect to “analysis readiness” of satellite data. Harvest lessons-learned include providing clear information on data availability (coverage, latency, accessibility and potential use). This challenge has resulted in standardizing vocabulary used for “validation” by the CEOS LPV.

The value of NISAR to GEOGLAM and Harvest will be in providing analysis-ready data (i.e., with minimal preprocessing needed – calibrated, orthorectified, filtered, masked for distortions, on the existing tiling system, and easy to access and use with higher order products). Such analysis-ready data may be in the form of tried-and-tested-for-ease-of-use toolbox for data processing. Alternatively, such data could be in the form of Level 3 data products such as crop type/area, crop condition, yield, 6-12 day soil moisture with well-documented (peer-reviewed) Algorithm Theoretical Basis Documents (ATBDs) and uncertainty reporting. Several opportunities for NISAR collaboration with Harvest exist, specifically through agriculture product and applications development, access to early adopters across the international community. GEOGLAM provides an opportunity for NISAR in terms of outreach and access to in situ data collection at the JECAM (Joint Experiment for Crop Assessment and Monitoring) sites. JECAM collects and shares time-series datasets, develops common standards in definition and reporting methods as well as field protocols, acquires and provides timely data and focuses on research for operational implementation.

5.12 Winrock International

The Winrock International mission is to empower the disadvantaged, increase economic opportunity and sustain natural resources across the globe using innovative approaches in agriculture, natural resources management, clean energy, and leadership development. The Winrock Ecosystem Services Team focuses on building capacity for land monitoring and management as well as developing decision support tools that leverage spatial data.

Winrock International works on US and international lands, with an emphasis on the developing world. The lands are typically covered in agriculture or forest, however there is a consistent shortage of land use information in the developing world often because of the low resources and technical capacity or because it is a smallholder-dominated landscape that is complex and difficult to quantify with remote sensing data. There is a confluence of outcomes (food, energy, and environment) that are driven by decentralized land-use decisions of smallholders.

Winrock International routine monitoring includes providing consistent long time-series of data for transparent demonstration of commodity company compliance with sustainability policy and national progress towards greenhouse gas commitments. This data are used for monitoring policy impact and having a consistent basis for planning as such continuity is more important than using the cutting-edge technologies.

Winrock International does not have a disaster response mandate.

The remote sensing capability of the Winrock International includes use of remote sensing data in derived maps from models that project impact of land use decisions on hydrologic, carbon, soil, and ecosystem services (e.g., administrative units, economic land concessions, protected areas, forest community, land cover, sediment erosion prevention, nutrient erosion prevention, biodiversity, etc.). These maps are accessible via a web-based interface. Remote sensing data are used for land use change monitoring with a particular focus on how such data are useful for greenhouse gas inventory systems.

The biggest challenges for Winrock International include meeting the expectations of users for the use of remote sensing data; categorizing complex landscapes; standardizing approaches to link continuous indices to manageable features; access to off-the-shelf indices that can be used in low-capacity environments; and data management. Many users expect remote sensing data to "just work" and governments will use whatever they can get most easily, but managing this expectation is challenging. This is especially true in developing countries that have complex environments with fragmented, decentralized land use that is not easily translated in the wanted categorical maps. Further complicating this is the need to standardize approaches that integrate multispectral, structural and temporal information into indices relating to managed features. Because of this difficulty, off-the-shelf indices and maps get much more use in low-capacity environments. Lastly, many users rely on their desktop for data management either because of convention or policy (e.g., "ownership" of the data).

The value of NISAR to Winrock International will be in providing information in poor regions independent of cloud cover. Specific information of interest from NISAR include agricultural productivity in complex landscapes (mixed pixels and many gradients), tree cover in non-forested lands, land subsidence in tropical peatlands, intensification of existing land-use such as fallow/cultivation cycle, long-term variability in productivity over landscapes, and identification of low-suitability lands.

5.13 US Geological Survey (USGS) Famine Early Warning System Network (FEWS NET)

The USGS FEWS NET is an activity of the USAID Office of Food for Peace (FFP) that has the goal "to ensure that appropriate… emergency food aid is provided to the right people in the right places at the right time and in the right way." FEWS NET is comprised of Chemonics, Kimetrica, USGS EROS, University of California Santa Barbara, NASA Goddard Space Flight Center, University of Maryland, NOAA CPC/PSD, and USDA FAS. The USGS part of FEWS NET does this by supporting the remote sensing, data modeling, and geospatial data needs, which includes providing data and information in near-real time to USAID FFP and FEWS NET primary contractor (currently Chemonics).

The USGS FEWS NET works with agricultural lands globally (~75 food insecure countries) that can be either irrigated or rainfed, primarily focusing on regional staple crops (e.g., maize, millet, wheat, etc.).

USGS FEWS NET routinely monitors climate (precipitation and temperature), vegetation, and crop conditions and performance. The level of analysis depends on whether a country is "presence" that is directly monitored by FEWS NET staff working in a country office, or is a remote monitoring country, which is typically covered by analysts from the region using a lighter analytical approach (e.g., networks and remote sensing). USGS FEWS NET relies on satellite remote sensing and models to fill the gap and provide the basis for early detection of agricultural drought. As such, products include rainfall, vegetation, evapotranspiration, soil moisture, and crop condition anomalies (difference, % of normal, z-score) reported at pentadal, decadal, monthly and seasonal time intervals (pre-season, NRT, and seasonal summary). All products are examined in short and long time series.

USGS FEWS NET disaster response mandate is to monitor drought conditions and floods. Although FEWS NET monitors drought for local, national, and regional food security impacts, it does not monitor for potential food insecurity (famine) due to conflict. Floods monitoring is important for food security, thus FEWS NET monitors, alerts, and reports potential flooding.

The remote sensing capability of the USGS FEWS NET primarily relies on use of higher-level products such as MODIS NDVI (250 m resolution), evapotranspiration (1 km resolution), Snow water equivalent/depth (1 km resolution), land surface temperature (1 km resolution), and soil moisture (10 km resolution). Remote sensing data are incorporated into web-enabled, online tools, or provided for download from HTTP servers for food security analysts. The information gleaned from remote sensing data are integrated with info on market prices, nutrition, etc. and are provided in briefings to decision makers (USAID and partners).

The biggest challenges for USGS FEWS NET are in providing accurate and dynamic crop masks, crop calendars (not just start of season, but planting dates), accurate crop area estimates (planted and harvested per year for at least 5 years), accurate yield data, and assessments of impact of dry spells on crop conditions.

The value of NISAR to USGS FEWS NET will be in providing data everywhere (but especially in cloud covered areas) that can be used for estimating soil moisture, crop condition, crop stage, start-of season, flood mapping, snow mapping, monitoring rice and crops grown under the tree canopy. The biggest challenge will be in the short history of L-band data as FEWS NET report anomalies.

6 Information Product Requirements

In a facilitated discussion on the first day, the community identified four priority Level 3 information products that would benefit across agency/organization, thus increasing NISAR data utility: 1) soil moisture, 2) crop classification, 3) surface water extent/flood inundation, and 4) crop yield.

For a common soil moisture information product, the community converged on some specifications. The product should report both the soil moisture at a specified depth, with the possible addition of soil moisture anomaly. It should be georeferenced with quality flags that are quantifiable, repeatable and interpretable across different landscapes. Such a product would need to be higher resolution than SMAP or SMOS such that field scale (10-200 m pixel resolution) assessments could be performed. Depending on the application high spatial resolution would be more important than high temporal resolution, however, the community agreed that twice every 12 days would be sufficient provided that latency for obtaining the product was within 2 days of acquisition. The community recognized that while some applications may need higher temporal resolution (e.g., disease risk) or spatial resolution, models would be an adequate method to meet this need. In order to use models in this way, the key will be in providing repeat observations to capture the pre-season soil moisture necessary to initiate the process-based models. Lastly, the community agreed that such a product should be delivered as Geotiff and in a GIS software compatible projection.

For a crop classification information product, the community converged on some specifications as well. The most agreed upon specification was that to do good classifications in any area, quick pre-processing tools that work on radiometric and terrain corrected data are needed. More broadly, the community discussed the challenges associated with crop classification that need to be considered in any algorithm. Specifically, the community discussed multi-cropping and the need for time series of seasonal growth and productivity throughout the growing season to make a single classification in any given year. Although a time series may improve crop type classification, temporal speckle filtering might be what's needed for smallholder field scale classifications. The community also acknowledged that grazing lands are an important crop classification that must be considered and that perhaps phenology will be useful for distinguishing grasslands from rangelands. Any crop classification would need to be validated with ground truth of known fields. Lastly, whatever crop classification is provided, it must improve upon existing crop data layers (e.g., CDL).

For a surface water extent/flood inundation product, the community specifically called for a product that could provide flood mapping in areas where surface water is anomalous (i.e., not areas where there is normal flow). To do this, the use of L-band would be more useful than that from Ka-band or C-band because it can see through the canopy. Because of the high temporal resolution needed to capture flood events (even as a single snapshot of a major event), the community suggested using the full SAR constellation. This would enable more rapid access to data for disaster response.

For crop yield, the community agreed that the product needs to consider multi-cropping at sub-field scale. Because this is so challenging, the community suggested providing biomass or leaf area index instead. Such a product would need to be provided every 1-2 weeks depending on how fast the crops of interest grow. It was also noted that such a product could be used in relation to crop health to provide more context relevant to agriculture and food security applications.

7 Technical Gaps

In a facilitated discussion on the second day, the community discussed technical gaps that need to be closed between the workshop and NISAR launch. One technical gap was in the availability of cloud processing tools to subset to regions of interest (e.g., administration polygons) and derive desired products. Because of the expected data volume, quick and easy access to the data via such tools will be especially important during disasters for high-speed transfers. Not only must such tools be made available, but also the skills/competency of different users for using them must be increased. To do this, it was recommended that NISAR leverage the historical record by releasing demo datasets (e.g., Sentinel-1) from previous missions simulated to 12-day repeat. Such simulated datasets would enable users to practice working with data ahead of launch, which would build trust within user communities. While awareness and trust of NISAR data is necessary at multiple levels (lower level/on the ground as well as upper management) of decisions/operations, the community recommended getting the "translators" of different agencies involved first to help bridge technical skill levels. One such "translator" identified that was missing from the participant list was ENVI as they can help figure out how to quickly integrate SAR software processing algorithms (e.g., ISCE) into their existing and widely used core software.

- limited availability and little to no open access to operational SAR observations
- lack of consistent, large-area acquisition strategies
- complex data structures relative to optical data
- lack of established modules, recipes, and workflows for agriculture applications of SAR

8 Roadmap to Launch

In the near term before NISAR launch (expected January 2022), it was suggested that an Agriculture and Soil Moisture Applications Working Group (as per the specifications of the NISAR Utilization Plan) would be useful. Such a working group would focus on: 1) calibration and validation of algorithms for Level 3+ information products relevant to the agriculture and soil moisture communities, 2) increasing SAR literacy among the broader agriculture and soil moisture community, and 3) developing a path for using NISAR data in response to the international disaster charter, which many of the agriculture and soil moisture communities are connected.

For calibration and validation, there was a lot of interest in both pre-launch algorithm calibration activities and post-launch validation activities. In both pre- and post-launch activities it was mentioned that a working group to discuss the best approach for ensuring that confidential field data is kept confidential, especially when talking about a cloud processing environment for the science data system. Along this vein, the community discussed key mutually beneficial terms for partnerships between SMAP and field data collectors that were successful. In particular, SMAP provided early access to data before public release during the 6-month check-out period. SMAP also established a policy that if any Science Team member or project member published using field data, that partner was named on the publication. Some additional mutual incentives for collaboration discussed were that NISAR algorithms for Level 3+ products would be more naturally tailored to sites and that if multi-frequency SAR could be provided, that would provide additional incentive. Lastly, the community was very supportive of the 12-day repeat airborne campaign to help improve understanding of how algorithms are affected by temporal variability and thought that this would be a key aspect of the working group, especially because people that worked with SMAP and SMAPVEX campaigns could participate and integrate lessons learned into any future NISAR airborne campaign. Other suggested participants would include members from existing programs such as EOFSAC, JECAM, NEON, LTAR, CRN, COSMOS and SCAN.

For increasing SAR literacy, participants had several recommendations which they thought a working group could help implement. First, they recommended leveraging the Inter-American Institute for Cooperation on Agriculture (IICA) as a conduit for providing learning materials. Workshop participants recommended training the next generation of “professionals” at universities, specifically targeting GIS centers at universities to “get it [NISAR] on their radar”. To gain the interest of these students, it was recommended that courses not be targeted at electrical engineers with a heavy physics focus, but rather focus on the information/application first and SAR physics to provide context for interpretation. Lastly, it was recommended that trainings need follow-up. Demo datasets are needed to accomplish this.

For disasters, workshop participants expressed the need to consider how the agriculture and soil communities would use NISAR data to help respond to the international disaster charter, as many must respond to such states of disaster. In particular, the community expressed the need to discuss more specifically desired latency versus time to nearest downlink station, order of data download, metadata download, and time needed for basic SAR processing like geocoding or even more so for higher level products that could help inform early warning systems related to food security and agriculture.

In summary, workshop participants identified three key objectives for a working group to address in the years between now and NISAR launch that would increase the utility of NISAR for the broader agriculture and soil moisture communities.

9 Appendices

9.1 Agenda

DAY 1: Tuesday, June 26, 2018

8:30-8:45	*Arrival & Sign-In*	
NISAR Introduction		
8:45-8:55	Workshop Welcome and Objectives	Mike Cosh (USDA) and Natasha Stavros (JPL)
9-9:20	NASA Welcome	Craig Dobson, NASA/HQ/Earth Science Division, NISAR Program Scientist
9:20-9:35	USDA Program Mission Overview	Teferi Tsegaye, USDA ARS National Program Leader
9:35-9:50	Satellite Needs Working Group	Glenn Bethel, USDA
9:50-10:20	NISAR Overview	Paul Siqueira, UMass, NISAR Science Team
10:20-10:30	NISAR Utilization Plan	Natasha Stavros, JPL, NISAR Deputy Applications Lead for Ecosystems
10:30-10:45	BREAK	
Agricultural and Soil Moisture Applications - Existing User Practices and Requirements		
10:45-11	USDA NASS - CDL/CropScape	Rick Mueller
11-11:15	USDA FAS	Bob Tetrault
11:15-11:30	USDA ARS	Mike Cosh
11:30-11:45	Canadian AAFC	Catherine Champagne
11:45-12	National Drought Mitigation Center	Brian Wardlow
12-1	LUNCH	
Agricultural and Soil Moisture Applications - Existing User Practices and Requirements (Continued)		
1-1:15	Climate Corporation (Monsanto subsidiary)	Xiaoyuan Yang
1:15-1:30	DuPont Pioneer	Olaniyi Ajadi
1:30-1:45	Applied Geosolutions	Xiaodong Huang
2-2:15	GEOGLAM and FSAC	Chris Justice, University of Maryland
2:15-2:30	CCAFS/Winrock	Kevin Brown, WInrock
2:30-2:45	FEWSNET	Jim Rowland, USGS
2:45-3	BREAK	
3-3:45	Breakout Sessions (SM, crop classification, yield) on product definition and specifications ● What is the best way to incorporate NISAR radar products into existing practices? ● What are the final products? What do the final products look like? ● Can the final product(s) be shared by multiple agricultural applications? ● What is the best way to deliver the final product?	

3:45-4:30	Breakout Debrief and Focused Discussion (Gerald Bawden as facilitator): What are the highest priorities? What is feasible with what NISAR will provide? What's the roadmap between now and launch? What does this mean for NISAR; e.g., do we need to establish a Working Group (analogous to SMAP "early adopters")? How does it affect observation strategy?

DAY 2: Wednesday, June 27, 2018

8:30-8:45	*Arrival & Sign-In*	
Agricultural Applications - SAR Examples		
Algorithm Developments		
8:45 - 9:15	Crop Classification and Extent	Paul Siqueira, UMass, NISAR Science Team
9:15 - 9:45	Crop Biomass/Health and Risk	Heather McNairn, AAFC
9:45 - 10:15	Soil Moisture	Wade Crow, USDA-ARS
10:15 - 10:30	Break	
Operational Integration of Remote Sensing		
10:30 - 10:45	Monitoring Rice Extent, Growth and Production	Nathan Torbick, Applied Geosolutions
11:15 - 11:30	Soil Moisture	Claire Boryan at USDA NASS, SMAP Early Adopters
11:30 - 11:45	Crop Classification	Catherine Champagne, AAFC
11:45-12	SMAP Early Adopter - Foreign Agriculture Service (Crop Explorer)	Iliana Mladenova, NASA GSFC
12:00-1:15	Lunch	
Bridging the Gap between NISAR and Existing Practices		
1:15-1:30	Big Data handling - Cloud computing for SAR	Josef Kellndorfer, Earth BigData, NISAR Science Team
1:30-1:45	SAR Data Availability (Sentinel-1, ALOS, UAVSAR, etc.) and Future Acquisitions	Tracy Whelen, UMass Amherst

1:45 - 2:30	Discussion (facilitated by Natasha Stavros)- What else do we need to consider to prepare for integrating NISAR once it launches? Models that create a consistent product across missions? Other multi-mission observation strategies for consistent products?	
2:30-2:45	Break	
NISAR Cal/Val		
2:45-3	NISAR Cal/Val Plan and Needs	Paul Siqueira, UMass, NISAR Science Team
3-3:15	JECAM	Heather McNairn, AAFC
3:15-3:30	Leveraging SMAP Cal/Val	Mike Cosh, USDA ARS
3:30-4:15	Structured Discussion facilitated by Paul Siqueira ● What further cal/val data is needed? ● Any additional cal/val partners? ● Expectations for partners, and what could they expect in return?	
4:15-4:30	Wrap-up and Work Plan: Steps needed before now and launch - working groups?	Natasha Stavros (JPL/NISAR Deputy Applications Lead for Ecosystems)

DAY 3: Thursday, June 28, 2018

9:00-12:00	*OPTIONAL* *Drafting an Ag and/or Soil Moisture Working Group* ● *Defining a Charter* ● *Defining Tasks/Deliverables* ● *Identifying responsible parties* ● *Preliminary Roadmap/ Timeline* *Agriculture and Soil Moisture Capacity Building Discussion* ● *SAR Literacy current plans* ● *Synergies*

9.2 Participants

Last Name	First Name	Affiliation
Ajadi	Olaniyi (Niyi)	DuPont Pioneer
Bawden	Gerald	NASA HQ
Bethel	Glenn	USDA
Boryan	Claire	NASS
Brown	Kevin	Winrock
Champagne	Catherine	AAFC
Cosh	Michael	USDA ARS
Crow	Wade	USDA ARS
Dobson	Craig	NASA HQ
Huang	Xiaodong	Applied Geosolutions
Justice	Chris	UMD/GEOGlam
Kellndorfer	Josef	Earth BigData
McNairn	Heather	AAFC
Mladenova	Iliana	NASA GSFC
Mueller	Rick	USDA NASS
Rowland	Jim	USGS
Siqueira	Paul	Umass
Tetrault	Bob	USDA FAS
Torbick	Nate	Applied Geosolutions
Tsegaye	Teferi	USDA ARS
Wardlow	Brian	NDMC
Whelen	Tracy	Umass
Yang	Xiaoyuan	Climate Corporation
Blankenship	Clay	NASA MSFC
Bosch	David	ARS
Coffin	Alisa	ARS
Cole	Chris	BLM
Colson	Lisa	USDA FAS
Davidson	Andrew	AAFC
Dobrowolski	Jim	NIFA
Edwards	Laura	SDSU
Forgotson	Chalita	NASA GSFC
Gao	Feng	
Hakimdavar	Raha	USFS
Hively	Wells (Dean)	USGS

Jiang	Pingping	
Kim	Sab	JPL
Lawston	Tricia	NASA
Lei	Fangni	USDA
McKinley	Duncan	USFS
O'Neill	Peggy	NASA GSFC
Oliphant	Adam	
Osmanoglu	Batu	NASA GSFC
Owen	Sue	JPL
Painter	Jamie	USGS
Poole	Madeline	USDA FAS
Pope	Chris	
Ravelo-Solano	Patricia	USDA FAS
Reist	Ben	USDA NASS
Reitz	Meredith	USGS
Rippey	Brad	USDA
Rose	Shannon	Umass
Schomberg	Harry	USDA ARS
Skakun	Sergii	NASA EOFSAC
Solak	Hayley	
Stavros	Natasha	JPL
Torak	Lynne	USGS
Williamson	Tanja	USGS
Yadav	Sunita	NGIA
Yao	Tian	NASA GSFC
Zhan	Xiwu	NOAA
Zhang	Huihui	USDA ARS

9.3 Acronyms

AAFC	Agriculture and Agri-Food Canada
ACGEO	Agroclimate, Geomatics and Earth Observation Division
AgRISTASRS	Agricultural and Resources Inventory Surveys Through Aerospace Remote Sensing
APHS	Animal and Plant Health Services
ARS	Agricultural Research Service
ATBD	Algorithm Theoretical Basis Document
CDL	Cropland Data Layer
CHIRPS	Climate Hazards Group InfraRed Precipitation with Station data
CONUS	Continental United States
CRN	Climate Reference Network
DMC	Disaster Monitoring Constellation
EO	Earth Observations
EOFSAC	Earth Observations for Food Security and Agriculture Consortium
FAS	Foreign Agricultural Service
FEMA	Federal Emergency Management Agency
FEWS NET	Famine Early Warning System Network
GDP	Gross Domestic Product
GEOGLAM	Group on Earth Observations Global Agriculture Monitoring
GIS	Geographic Information System
GPM	Global Precipitation Measurement (mission)
ISCE	InSAR Scientific Computing Environment
ISRO	Indian Space Research Organization
JECAM	Joint Experiment for Crop Assessment and Monitoring
LACIE	Large Area Crop Inventory Experiment
LTAR	Long-Term Agriculture Research
MODIS	Moderate Resolution Infrared Spectroradiometer
NADM	North American Drought Monitor
NASA	National Aeronautical and Aerosopace Administration
NASS	National Agricultural Statistics Service
NDMC	National Drought Mitigation Center
NEON	National Earth Observing Network
NISAR	NASA-ISRO Synthetic Aperture Radar
NOAA	National Oceanic and Atmospheric Administration
NRT	Near Real Time
PALSAR	Phased Array type L-band Synthetic Aperture Radar (mission)
PDC	Pacific Disaster Center
QuickDRI	Quick Drought Response Index

SAR	Synthetic Aperture Radar
SCAN	Space Communications and Navigation
SMAP	Soil Moisture Active Passive
SMOS	Soil Moisture Ocean Salinity
SNWG	Satellite Needs Working Group
TAOS	The Arbiter of Storms
TRMM	Tropical Rainfall Measuring Mission
USAF	US Air Force
USAID FFP	USAID Food For Peace
USDA	US Department of Agriculture
USDM	U.S. Drought Monitor
USGS	US Geological Survey
VegDRI	Vegetation Drought Response Index
VIIRS	Visible Infrared Imaging Radiometer Suite
WMO	World Meteorological Organization